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SOME PECULIARITY OF ELEMENT ANALISYS USING CHARGED PARTICLE BEAMS

A.P.Kobzev[1], S.M.Abu Al Azm[1], A.I.Helal[2], N.F.Zahran[2]

[1] *Frank Laboratory of the Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russia*

[2] *Nuclear Research Center Atomic Energy Authority, Cairo, Egypt*

Abstract

Multilayer structures, SiC –layers at Si substrate, have been analyzed by RBS, NR, ERD and PIXE methods using the charged particle beams from EG-5 Van de Graaff accelerator of JINR. The depth profiles of the based deposited layers were obtained for the multilayer structures.

Keywords: *RBS, ERD, Multilayer structure, Silicon Carbide Film*

Introduction

The different tasks of nuclear physics, solid state physics and applied problems could be solved using charged particle beams from the Van de Graaf accelerator of the Joint Institute for Nuclear Research at Dubna. The main parameters of the EG-5 accelerator are typical for this category of the accelerators:

Energy range – 0.8 – 3.5 MeV

Accelerated ions – ^{1}H, ^{2}H, ^{3}He, ^{4}He, ^{12}C, ^{14}N, ^{16}O

Beam current - 0.2 - 20 μA

Energy spread - < 500 eV

Accuracy in energy – 1 keV

The different equipment for the investigation of the element contents and a structure of solids by the nuclear methods such as Rutherford Backscattering Spectroscopy (RBS), Nuclear Reaction (NR), Elastic Recoil Detection (ERD), Particle Induced X-Ray Emission (PIXE), and Channelling are installed on the six beam lines of the EG-5 accelerator. Some peculiarity which has arisen in process of the decision of the different analytical and structural tasks are reviewed below.

Si/Ge multilayer structures

Multilayers have considerable interest as industrial materials because of their specific properties and many promising areas of applications in electronics or optics like X-ray and UV mirrors, giant magnetic resonance and magnetic recording, etc. However, the multilayers as artificial, compositionally modulated materials are not equilibrium structures. In particular, they have high interfacial density gradients and sufficient atomic mobility even at moderated temperatures, hence changes in the composition profiles are expected to occur.

Si, Ge and O depth profiling in the Si/Ge multilayer structure consisting of 5 bilayers has been performed by the RBS and NRA methods [1]. The determination of the depth profiles of oxygen atoms in the investigated samples was carried out using the ^{16}O $(\alpha,\alpha)^{16}O$ nuclear reaction. A number of spectra were measured for the different angles of the incident Energy

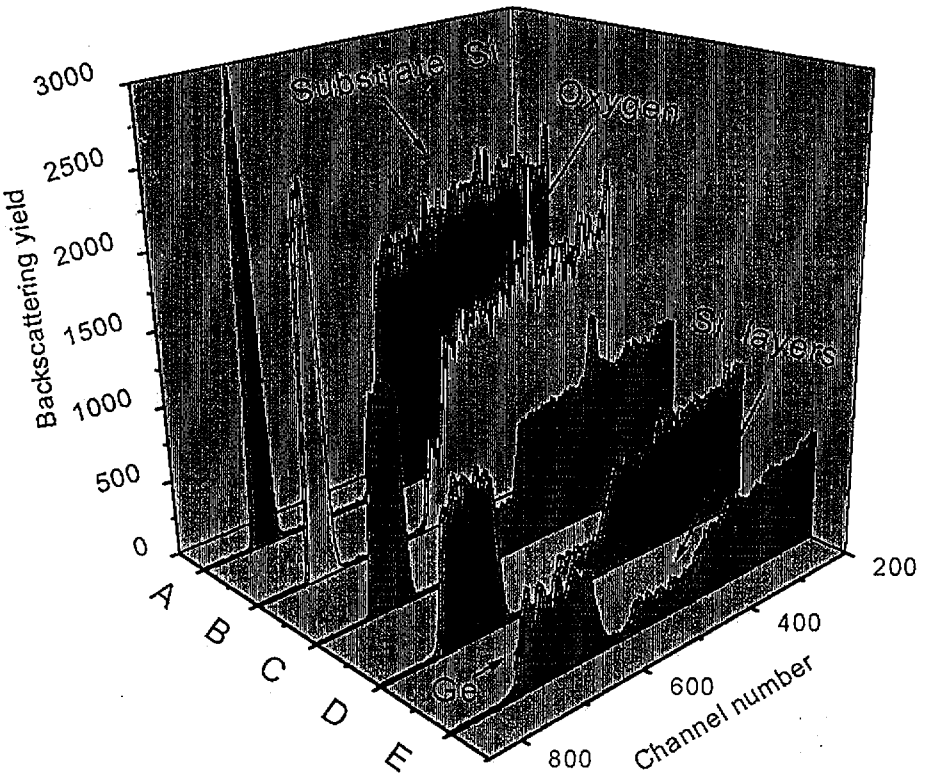

Fig. 1. spectra of 3.112 MeV ^4He ions scattered at 170° by the Si/Ge multilayer *structure. The incidence angle* $\varphi = 6^o - E$, $\varphi = 10^o - D$, $\varphi = 20^o$ - C, $\varphi = 40^o - B$, $\varphi = 60^o - A$.

beam with respect to the surface of the samples (φ ranging from 5^0 to 60^o) with 3.112 MeV helium ions.

Some of the measured spectra are shown in Fig.1. All silicon and germanium layers are seen in the spectrum as the separated peaks for $\varphi=6^o$. But the depth resolution is worse for deeper layers because of energy struggling. Nevertheless a layered structure with degraded interfaces is observed. From our analysis it is seen that all layers contain some oxygen impurity (10-13%), and a definite SiO_2 layer with a thickness of 177Å situated between the multilayer structure and the Si wafer is revealed. The oxygen peak pointed in Fig. 1 (spectrum B) corresponds to this layer. A sharp resonance in the ^{16}O $(\alpha,\alpha)^{16}O$ reaction for the 3.045 MeV is observed for all incident angles except $\varphi=60^o$ (spectrum A, fig.1). For this incident angle and an initial energy of 3.112 MeV of ^4He ions resonance occurs in an oxygen free substrate.

Modelling has allowed us to determine the full thickness of the Ge-layer which is about 130 Å and that of the Si layer to be about 231 Å, including the mixed layers with the thickness 64.7 Å. It is essential that the same model has been used for the description of all the experimental spectra obtained at different incident angles. So, a complete structure of the sample has been reconstructed by this non-destructive technique.

Neutron polarised mirrors

The supermirror neutron guides consist of the alternating magnetic and unmagnetic layers (usually FeCo and TiZr layers) deposited on the glass substrates. Such neutron guides allow to transport the neutrons at the tens meters away from nuclear reactor where the backgroundless conditions can be supplied for an experimental setup. Besides, the neutrotics devices are capable to produce the polarised monochromatic neutron beams.

Some important problems raised in producing process of the effective mirror devices are : a violation of the optimal ratio between Fe and Co, Ti and Zr in the apropriate layers, the roughness of the surface and interfacial diffusion which create together mixing layers, the presence of different impurities (O, Ar, N,C). The RBS investigation at $^4He^+$ beam allows to solve all these tasks [2]. As an example, we will discuss the results of investigation of multylayer structure consisting of 12 pairs of FeCo/TiZr polarising layers and one GdTiZr absorbtion layer. In order to reach the better depth resolution a glancing experimental geometry was applied.

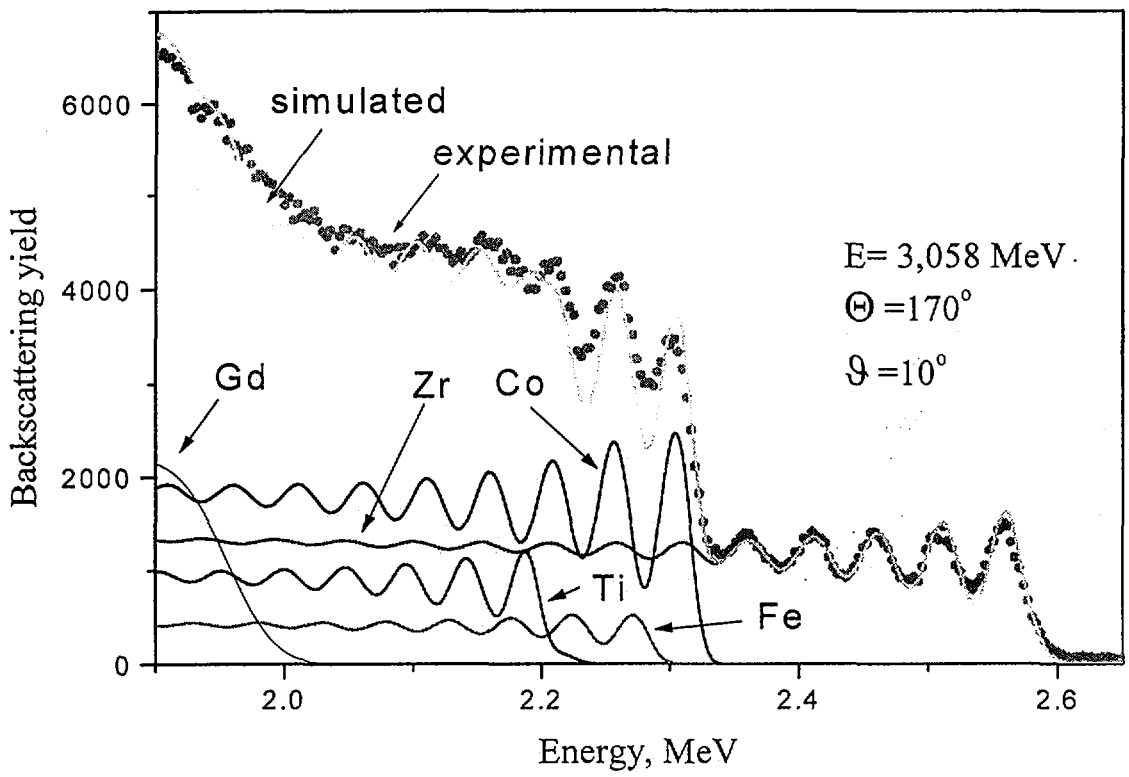

Fig.2. Spectra of 3.058 MeV ^{4}He ions backscattered at TiZr/FeCo multilayer structures with period of 15.3nm. Partial spectra for heavy elements are shown.

The spectrum of ^{4}He ions with initial energy of 3.058 MeV bombarding the target under the incident angle 10° is shown in Fig.2. Though some superposition of the partial spectra is observed and influence of the struggling takes place nevertheless the periodic structure according to the first five pair of layers one can see. The concentration depth profiles Ti, Fe, Co, and Zr have been derived from the simulation of this spectrum. In this way the thickness has been determined as 9.1 nm for TiZr-layers and as 6.2 nm for all FeCo-layers except second FeCo-layer which contained 16.3% oxygen and thus its thickness was 7.4nm.The oxygen depth profile has been derived from another spectra measured for the different incident angles.

Fig.3 shows spectrum for the incident angle of 38° when narrow resonance at 3.045 MeV in elastic scattering of ^{4}He ions is placed in second layer. From this spectrum we can also see some violation from the homogeneity of absorbtion sublayer in which Gd and Zr

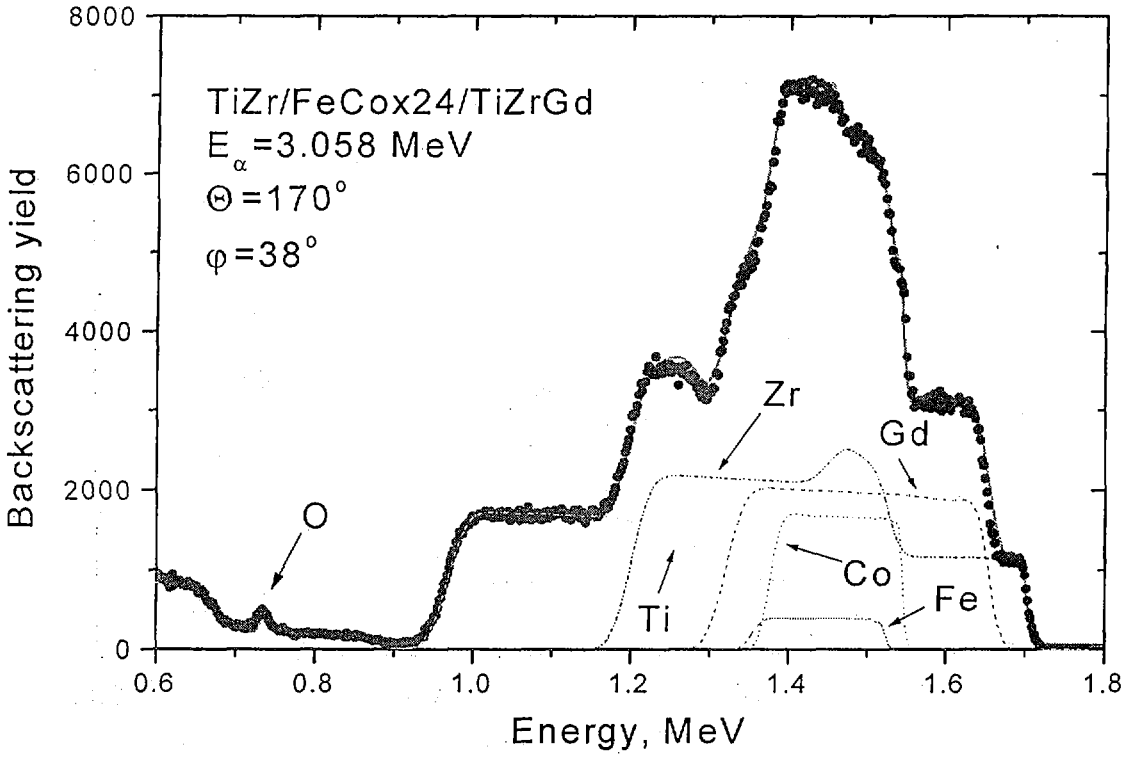

Fig.3. Experimental and simulated spectra for the incident angle of 38° obtained at TiZr/FeCo multilayer structure.

depth concentrations change within the layer, whereas Ti contents stay constant. The thickness of the absorbtion sublayer staying at 257 nm depth was determined as 473 nm. The concentration Fe, Co, Ti, and Zr stays also constant over everything 12 pairs of refraction layers. The finishing results giving the best description of all experimental spectra are illustrated in Fig.4. So, using RBS method one can derive a lot of information concerning the element contents and structure of the multylayer neutron polarised mirrors without their damaging.

Silicon carbide films

Most traditional integrated circuit technologies using silicon devices are not able to operate at temperatures above 250°C, especially when high operating temperatures are combined with high power, high frequency and high radiation envirnoment. Much attention has been given to SiC, currently the most mature of the widebandgap (2.0 eV < E_g < 7.0 eV)

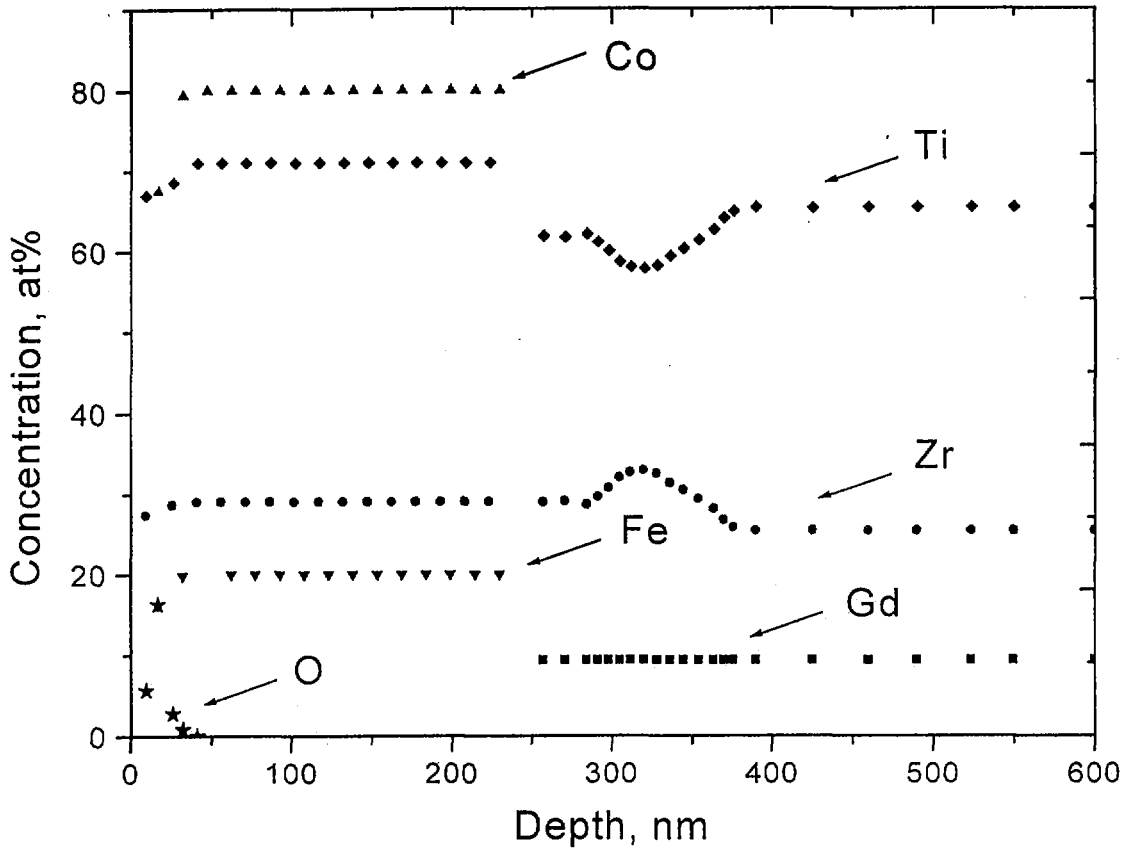

Fig.4. Element depth distribution for TiZr/FeCo multilyer structure *derived from RBS and NRA experiments.*

semiconductors, as a material well-suited for high temperature operation. High-temperature circuit operation from 350°C to 500°C is desired for use in aerospace application (turbine engines and more electric aircraft initiative), nuclear power instrumentation, satellites, space exploration, and geothermal wells. In addition to high-temperature applications, SiC has potential for use in high-power, high-frequency, and radiation-resistant applications. Futhemore, SiC can also be used as a thin buffer layer for the growth of diamond films on silicon substrates. For example, a-$Si_{1-x}C_x$:H was used as a wide window material to enhance the conversion efficiency of amorphous solar sell. The significance of this material follows from the fact that its electrical and optical properties can be controlled by varying the carbon, silicon and hydrogen composition in the film. The actual amounts of carbon, nitrogen, and oxygen in SiC films was determined by RBS method[3]. Such case is presented in Fig.5 where one can see the RBS spectrum for SiC-sample. At the spectrum one can substract the

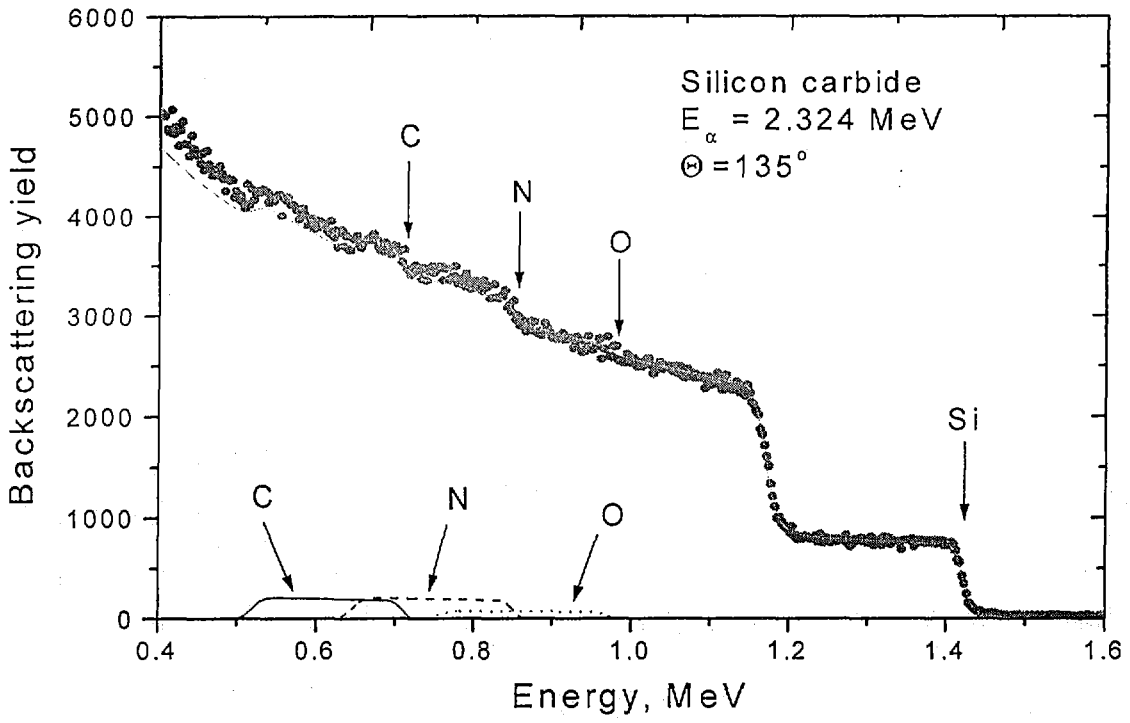

Fig. 5. Experimental and simulated spectra for SiC sample.
Partial spectra for C,N,O are shown also.

partial spectra scattered at all elements incoming in the sample except hydrogen. The hydrogen concentration was determined by the Elastic Recoil Detection (ERD) method. The spectrum of the recoiled H atoms was stored simultaneusly with the RBS spectrum. The computation of the both spectrum allows us to determine the thickness (435 nm) and the element contents of SiC film: Si-20%, O – 5%, N – 18%, C – 24%, H – 33%.

Conclusion

The anylsis of Si/Ge multilayer stractures showes all the layers contain some oxygen impurity and a definite SiO_2 layer situated between the multilayer structure and the Si wafer. From the anylsis of neutron polarised mirrors, the thickness of TiZr-layers about 9.1 nm and 6.2 nm for all FeCo-layers except second FeCo-layer which contained 16.3% oxygen and its thickness was 7.4 nm.

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